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STATISTICAL ANALYSIS OF KAMINURIAK CALVING GROUND SURVEY DATA, 1971-1974

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INTRODUCTION

Because of the rugged nature of the terrain, the enumeration of big-game populations in Canada's north is done almost entirely by aerial observations. Banfield et. al. 1955 (Trans. N. Am. Wildl. Conf. 20:519-530) contributed to the early development of aerial census procedures in the north, and Siniff and Skoog 1964 (J. Wildl. Manage. 28(2):391-401) produced a classic paper on stratified random sampling of caribou in Alaska which was to form the basis for most modern caribou census designs, and indeed, most aerial big-game census design in North America.

The basic stratified random sampling design developed by Siniff and Skoog was subsequently used by Parker 1972 (Can. Wildl. Serv. Rep. No. 20) for some of the early census work on the Kaminuriak calving grounds, and has been continued by the Northwest Territories Fish and Wildlife Service for these calving ground surveys up to the present time.

Interdisciplinary Systems Ltd. was asked to review the Kaminuriak calving ground census reports for the period 1971-1974 and report on:

1. The results of data analysis and precision estimates of the 1971-1974 calving ground data.
2. General recommendations on census and data analysis techniques available to improve the realiability of future calving ground censuses.

Visual Estimation Bias

The most questionable aspect of the 1971 and 1974 surveys (Table 1) is on the occurrence of a few blocks with very high caribou density. In these blocks, large groups of caribou cannot be counted exactly, and the size of large groups must be estimated. The results for the three blocks of highest density in the 1971 survey are based almost completely on these estimates, and are reported to be 2230, 4559 and 5851. Thus, a total of 12,640 caribou were estimated, while the total number of animals "observed" in the complete 1971 survey was only 14,173. The fact that only 11 percent of the total survey count is based on "accurate" counting of caribou within sample blocks is very disturbing and severely limits the researchers' ability to statistically estimate the population total and variance.

The 1974 survey appears to suffer from the same problem, although perhaps not to the same degree. Estimates were probably necessary on the two blocks with the highest densities of caribou. The "estimates" for these two blocks are 1255 and 1346, and their total comprised 43% of the total census count. In this survey, therefore, only 57% of the total is based on accurate counts.

Estimates of the number of individuals present in large aggregations are notoriously unreliable. The authors of the 1971 survey suggest that their counts may be too high. However, Thomas (Canadian Wildlife Service report series No. 9) reported that

le 1. Summary of Kaminuriak calving ground population estimates for the period 1968, 1971-1974.

	1968	1971	1972	1973	1974
ber of 16-square e blocks on ving ground	168	49	124	72	147
ple size	28	7	18	20	30
rage caribou/block	185.1	392.1	108.3	137.7	190.9
ndard deviation	175	817	169	228	313
imated calving ground ulation size ($\hat{y}$)	31,098	19,215	13,495	9,914	28,072
f width of a 95 per- nt confidence interval $\hat{y}$ as a percent of $\hat{y}$.	33%	178%	71%	66%	53%

estimates of the caribou herd were, on the average, about 20.7% too low. Bell et. al. 1973 (E. Afr. Wildl. J. 11:55-74) reported that estimates of the herd size of Kafu Lechwe were 37.7 percent, 14.2 percent and 17.3 percent too low in three consecutive years. In both of these studies exact counts were obtained from aerial photographs.

In summary, estimates, rather than actual counts of caribou present on sample blocks during the 1971 and 1974 surveys probably introduced a substantial bias as well as increasing the variability of the final population estimates. In any study of this nature it is very important that the amount of estimation be accurately recorded and that, if possible, internal measures of the bias and variability be available. As a general rule, the effects of bias on the accuracy of an estimate is negligible if the bias is less than one-tenth of the standard deviation. Any statistical treatment of the data from the 1971 and 1974 surveys would require that either the magnitude of the bias be assumed known or that it be assumed negligible. The problems with either of these approaches seem obvious.

Population Estimates

Any treatment of the data from these surveys designed to estimate population totals would seem to require,

a) an adjustment for the blind spot under the plane,

b) an adjustment for the bias present in estimating the size of large aggregations,

c) an adjustment for the unidentified animals in herd composition estimates, and

d) an adjustment or assumption about the amount of visbility bias caused by the failure to observe some animals or groups.

This seems to be an unreasonably large collection of adjustments to apply to a set of census data and still produce a statistically reliable estimate. Without the benefit of prior knowledge about any of these adjustments, the most reasonable approach to the analysis of the data from previous surveys would be to concentrate on total calving ground population estimates (females + unknowns + yearlings) and ignore all adjustments. This would be done with the understanding that resulting estimates would not reflect true population totals, but would provide some information about relative sizes of the calving ground populations.

In all four years (1971-1974) individual animals were classified as "adult cow", "yearling" or "unknown". The 1971 and 1972 census reports provide estimates of that segment of the calving ground population classified as "adult cow" or "unknown". Such population estimates are of little value since the definition of the target population depends on the observer's ability to classify animals. At best they provide upper limits for estimating the "adult cow" segment of the population.

The survey report for 1974 describes an attempt to more accurately estimate the total female population by establishing the composition of the unidentified herd component in each

mple block. The exact nature of this composition estimation rocedure is somewhat vague. Apparently, the estimates constitute ttle more than observer guesses. Using this procedure, the nal estimate (without the 20% correction for the area under the rcraft) of the female component of the calving ground population 21,325.

A second estimate of the female component may be obtained allocating unidentified animals to the adult cow and yearling lassifications in proportion to the number of females and yearlings ounted. This procedure requires the assumption that females and earlings are equally difficult to classify and results in a final stimate of 15,869. The point here is not to suggest that this is more reliable estimate, but rather to illustrate the arbitrary ature of results obtained from two seemingly reasonable methods f data analysis and interpretation.

In addition, in the 1974 report, an estimate of the otal Kaminuriak population was obtained by assuming that females omprise 57% of the total population and adjusting the estimate ccordingly. This seems to be another somewhat arbitrary adjustent based primarily on one earlier study.

Table 1 presents total calving ground population estiates without the 20 percent adjustment for the three years 1971-974. For comparative purposes, the corresponding results from arker's 1968 survey are also presented.

Superficially, it would appear that the population size ecreased in 1971, 1972 and 1973. However, it must be remembered hat the data for 1971 and 1972 are questionable: date from 1971

are suspect because of unreasonably high variance and because only 11 percent of the total is based on accurate counts. Data from 1972 are suspect because as stated in the report "...the results of this survey do not represent the herd, due to movement of animals, unfavourable viewing weather and poor ground conditions". This leaves only the data from 1973 to suggest a population decrease. However, because of the extremely large variability present in this survey (± 66 percent) the results for 1973 and 1974 do not differ significantly. (The two-sample t-test used here asks whether the sample means in row 3 of Table 1 for 1973 and 1974 have been drawn from the same infinite population.) In fact, none of the population estimates in Table 1 differ significantly and, based on the data in Table 1, no conclusions can be reached regarding the relative status of the Kaminuriak calving ground population during the period 1968-1974.

The extreme variability of these results is due to the occurrence of a few blocks with very high densities of caribou and a number of blocks with very low densities. Efforts to produce more accurate population estimates should concentrate on reducing this variability. Generally, this may be done by (a) refining the sampling technique to reduce variance and/or (b) increasing the sample size (i.e. the number of blocks sampled). A discussion of alternate sampling techniques is outside the scope of this report; however, an idea about the required sampling intensity may be obtained from the data for 1972.

Table 2 gives the sample size necessary to be within (P) percent of the true total population (assumed to be 13,500) with

Table 2. Sample size requirements to be within a given percent (P) of the 1972 calving ground population estimates at $P<0.05$.

Percent (P)	Required sample size (n)	Percent sampling Intensity {100 (n/124)}
5	120	97
10	110	89
20	81	65
30	57	46
40	41	33

a 95 percent probability. Clearly, the sampling intensity required to achieve a reasonable degree of precision is very large. Also, the sampling intensities for the years 1971, 73 and 74 are at least as large as those presented in Table 2: Table 3 lists the sampling intensity required to be within 20 percent of the true total population with a 95% probability for each year analyzed is presented in Table 3.

Le 3. Summary of sampling intensity required for a population estimate ± 20 percent at $P < 0.05$.

r	Number of 16-square mile blocks on calving ground size (n)	Required sample size (n)	Percent sampling intensity {100 (n/N)}
8	168	59	35
1	49	44	90
2	124	81	65
3	72	62	86
4	147	96	65

This review of the 1971-1974 Kaminuriak calving ground census data indicated major problems with visual estimation bias, the effectiveness of the sampling design, and data analysis and interpretation.

The non-random distribution of caribou during what appears to be the majority of years, results in some quadrats having large numbers of caribou and some none, producing the visual estimation and variability problems outlined in Section two. This problem appears to be inherent to a 16-square-mile block design, and unless techniques can be developed to either measure or eliminate it, the sampling design will have to be changed.

Even if large group estimation problems can be eliminated, the caribou distribution, and the resultant high variance of a block sampling design, appears to require prohibitive sampling intensities for a statistically reliable estimate. It is possible that the 16-square-mile blocks reflect the case of variance peaking when block size approximates the caribou group size (Greig-Smith, p. 1964. Quantitiative Plant Ecology 2nd ed, Butterworth, London). This could possibly be rectified by a major reduction in block size, but the smaller blocks would, in turn, probably present insurmountable navigational problems for a fixed-wing aircraft. Because of these major technical problems with the block design, random or systematic transects may have to be considered for the calving ground census. Transects

(or strip plots) could help alleviate some of the problems encountered with the block survey, and although they present unique procedural and analytical problems of their own, they are capable of producing statistically reliable estimates of the population total and its variance.

The analysis and interpretation of the census results could be considerably improved. Two examples are used to illustrate this point. Although Siniff and Skoog carefully outlined the analysis methodology and formulaes for their technique, none of the 1971-1974 census reports provided an estimate of the variance of the population estimate. For that matter, Parker's 1968 data was also without an estimate of variance. Such estimates of the mean or total without an accompanying estimate of variance are almost completely useless, since the reader has no idea what relative relability to attach to the estimates. Another example is found in the estimates for "adult cows", "unknowns", and "total" described in the section on population estimates. The procedures and definitions for obtaining these estimates were not clearly defined, and in some cases were left to the interpretation of the reader.

The enumeration of big-game populations is a statistical problem and the census design, analysis and interpretation requires considerable statistical expertise.

Our examination of this census data indicated that the statistical problems outlined above have not been adequately addressed. Consequently, statistically reliable estimates of

caribou population numbers on the Kaminuriak calving ground are not available for the period 1971-1974, primarily as a result of the extreme variability inherent in the estimates.

It is our opinion, therefore, that the existing survey is inadequate to obtain reliable estimates and that it should not be continued as currently designed and conducted. The following section contains some general recommendations that may be appropriate to the development of an improved sampling design.

1. Develop a carefully designed census procedure that will provide statistically reliable estimates adequate to meet herd management objectives. Inherent in this recommendation is the understanding that calving ground estimates provide only a portion of the information required for total herd management. Consequently, the calving ground census should be developed in conjunction with, and integrated into, a total herd information system.

2. Techniques should be developed within the framework of the sampling design to either eliminate or measure the bias resulting from estimating large groups. Inherent in this recommendation, but not discussed in the text, is the ability to also measure the potential visibility bias of missing entire groups.

3. Once the sampling design has been determined, procedures for conducting the census should be carefully worked out with field staff, carefully documented, and strictly adhered to. This is a very important step since it allows some reduction in variance by careful design, but probably more important, strict adherence to a consistent set of procedures greatly reduces between year variance and facilitates interpretation of results.

5. Analysis techniques for the census data should be thoroughly documented and computerized. This will allow for consistent results between years regardless of staff experience or turnover.

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